Lasers in Surgery and Medicine 19:135–142 (1996)

Visual Laser Ablation of the Canine Prostate With a Diffusing Fiber and an 805-Nanometer Diode Laser

Douglas M. Cromeens, DVM, Douglas E. Johnson, MD, L. Clifton Stephens, DVM, PhD, and Kenneth N. Gray, DVM, MS

Department of Veterinary Medicine and Surgery, University of Texas M. D. Anderson Cancer Center, Houston, Texas 77030 (D.M.C., L.C.S., K.N.G.); Department of Urology, St. Joseph Hospital, Houston, Texas 77002 (D.E.J.)

Background and Objective: **Although the popularity of visual laser ablation of the prostate (VLAP) as a treatment for symptomatic, benign prostatic hyperplasia (BPH) is increasing, the perceived advantages of VLAP over conventional transurethral electroresection of the prostate (TURP) is being debated because optimal technique and dosimetry for surgical lasers are still being refined. At this time, the 1.06 neodymium:yttrium-aluminum-garnet (Nd:YAG) laser and a laterally deflecting delivery system is the hardware combination most widely used for VLAP.**
Study Design/Materials and Methods: **Reported here is a study of an alternate system, a 805-nm diode laser (Diomed 25® Diomedics, The Woodlands, TX) with a cylindrically diffusing fiber (Surgimedics Inc., The Woodlands, TX). Eight mongrel dogs were prostatectomized by transurethral irradiation of the prostate with 15,000 J of diode laser energy delivered via a fiber that diffuses the energy in a 1.5-cm-long cylindrical pattern. The dogs were sacrificed and prostates harvested at 3 hours and 1, 4, 7, 14, 21, 35, and 49 days after the procedure, fixed with 10% buffered formalin, and examined histologically.**
Results/Conclusions: **It was found that this laser/fiber combination created volumes of tissue coagulation similar to those encountered in our previous work with the Nd:YAG laser in combination with both laterally deflecting and diffuser fibers, while offering the distinct advantages of simplified technique, lower cost hardware, and fewer postoperative complications in the dog model.**

Key words: neodymium:YAG, TURP, VLAP

INTRODUCTION

The use of the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser with a laterally deflecting quart fiber for performing transurethral prostatectomies in the dog was first reported by Johnson et al. in 1991 [1]. Since that time, variations on that technique in the dog have been adapted for treatment of symptomatic benign prostatic hyperplasia (BPH) in men, with similar, if not better, results when compared with those of conventional transurethral resection of the prostate (TURP) [2–8]. Although controversy still exists concerning optimum dosimetry, the efficacy and safety of treating BPH with visual laser ablation of the prostate (VLAP) using the ND:YAG/laterally deflecting fiber combination is gaining wide acceptance. The ability of VLAP to successfully treat BPH with lower complication rates and fewer hospital days is moving urologists toward

Accepted for publication November 3, 1995.

Address reprint requests to Dr. Douglas M. Cromeens, Department of Veterinary medicine and Surgery, The University of Texas M. D. Anderson Cancer Center, 1515 Holcombe Blvd., Box 63, Houston, TX 77030.

performing the procedure on an outpatient basis [7].

While current VLAP techniques offer documentable advantages over TURP, it is not without drawbacks. The high cost of the hardware (both lasers and fibers), persistent irritative symptoms in some patients postoperatively, and poorly delineated dosimetry for different-sized prostates all contribute to delaying the movement of VLAP from the operating room to the urologist's office.

The ability of cylindrically diffusing fibers to duplicate the photocoagulation volume of laterally deflecting fibers at similar doses of Nd:YAG irradiation has already been demonstrated [9]. This study sought to evaluate the efficacy of the 805-nm diode laser in combination with a diffuser fiber to photocoagulate the canine prostate and to characterize the pathologic changes that occur in the prostate after treatment with this wavelength laser delivery system.

MATERIALS AND METHODS

Eight mature intact male mongrel dogs weighing from 22.8 to 31.6 kg were preanesthetized with acepromazine (0.22 mg/kg) and atropine (0.05 mg/kg) intramuscularly. General anesthesia was induced with intravenous thiopental sodium (20–25 mg/kg), and after orotracheal intubation, was maintained with a 0.5–2.0% halothane-oxygen mixture given through a semiclosed circle system. A 10-French polypropylene urethral catheter was passed into the urinary bladder, and the abdomen was prepared for aseptic surgery.

After a caudal midline incision exposed the urinary bladder and prostate, a 21-French cystoscope (Olympus, Lake Success, NY) was inserted via cystotomy into the urinary bladder and secured with an 0 chromic purse-string suture. Prostates were measured in three dimensions after the periprostatic fat was removed. The length (measured from cranial to caudal limits) of the prostates ranged from 3.0 to 5.0 cm (3.9 cm average). The tip of the urethral catheter was positioned caudal to the colliculus seminalis and attached distally to normal saline irrigation fluid. The cystoscope was placed into the prostatic urethra, and the 1.5-cm-long Surgimedics/ESP 9S-5270 (Surgimedics Inc., The Woodlands, TX) fiber tip was advanced through the cystoscope and centered over the colliculus seminalis. The 9S-5270 fiber tip consists of a 600-m quartz fiber with a 15-mm opaque diffuser tip protected by a smooth Teflon™ cover. Diffused optical radiation is emitted in a symmetrical radial pattern that produces an elliptical zone of coagulation. After the fiber was in place, room-temperature saline irrigation fluid was applied through the cystoscope as well as the urethral catheter and was drained through the cystoscope. Lasing was monitored and recorded on videotape.

Lasing was begun using an 805 nm Diomed 25™ diode laser (Diomedics, The Woodlands, Texas). Fifteen thousand joules (25 Watts for 10 min) was delivered in one continuous dose to the prostate through the diffuser fiber. After lasing, the urethral catheter was advanced to the level of the bladder neck, and the cystotomy was closed with two continuous layers of 3-0 chromic catgut. The abdominal muscle and subcutaneous tissue were closed with simple interrupted 2-0 polyglactin 910 sutures, and the skin was approximated with 3-0 monofilament wire in a simple interrupted pattern. The urethral catheter was sutured to the prepuse with 3-0 silk and cut short enough to discourage postoperative removal by the dog.

Postoperatively, all dogs received 500 mg chloramphenicol orally three times daily for 7 days. The urethral catheters were removed after 24 hours, and the dogs were observed daily for signs of dysuria or incontinence. The dogs were humanely killed at 3 hours and at 1, 4, 7, 14, 21, 35, and 49 days by exsanguination after induction of general anesthesia with 20 to 25 mg/kg pentobarbital sodium. The urogenital tract was removed and partially inflated with 10% buffered formalin, and fixation was completed by submersion in the formalin solution. Following fixation, the prostate was step-sectioned in the coronal plane at approximately 3-mm intervals from the caudal to the cranial end. The sections for microscopic examination were taken from the approximate mid portion of the crossly altered segment that received the laser treatment. Following routine processing and embedding in paraffin, sections were cut at 3–5 μm and then stained with hematoxylin and eosin.

RESULTS

Clinical

The postoperative period was without major complications in all eight dogs. One dog required recatheterization 3 days after surgery because of urine retention. This catheter was removed 5

TABLE 1. Illustrations*

Dog No.	Survival time	Max. diameter	Width	Length	Volume
7253	3 hours	2.2 cm	2.2 cm	2.0 cm	4.59 cm^3
1430	24 hours	1.8 cm	1.8 cm	1.7 cm	2.87 cm^3
1332	4 days	2.3 cm	2.3 cm	2.8 cm	7.73 cm^3
1102	7 days	2.0 cm	2.0 cm	1.8 cm	3.76 cm^3
1587	14 days	2.7 cm	2.7 cm	2.0 cm	7.61 cm^3
793	21 days	1.1 cm	1.1 cm	1.5 cm	1.32 cm^3
1036	35 days	2.0 cm	2.0 cm	2.0 cm	4.18 cm^3
645	49 days	2.6 cm	2.6 cm	2.7 cm	9.53 cm^3

*Volume of the ellipsoid-shaped prostatic defect was calculated by using the following formula: $4/3\ \pi$ (depth/2 $\times$ width/2 $\times$ length/2).

days later. The dog killed 7 days postoperatively exhibited moderate scrotal and prepuceal edema at the time of sacrifice. Hematuria was a common observation for 3–5 days postoperatively in all the dogs. None of the other dogs displayed any sign of dysuria or incontinence. All dogs were able to void urine satisfactorily following removal of the urethral catheter.

Gross and Histopathologic Examination

The maximum diameter, length, and volume of the prostatic defects are listed in Table 1.

In the prostate harvested 3 hours after laser treatment, the prostatic urethra was surrounded by an approximately 1.5-cm radial zone of coagulative necrosis (Fig. 1). Within the area of necrosis, there were changes in tissue birefringence characteristic of photothermal damage [10]. The prostatic urethra was ulcerated, and the necrotic region contained multifocal hemorrhage and thrombosis of widely scattered blood vessels. Interstitial edema was present throughout the gland (Fig. 2).

The prostate harvested 1 day after surgery exhibited a zone of coagulative necrosis similar in

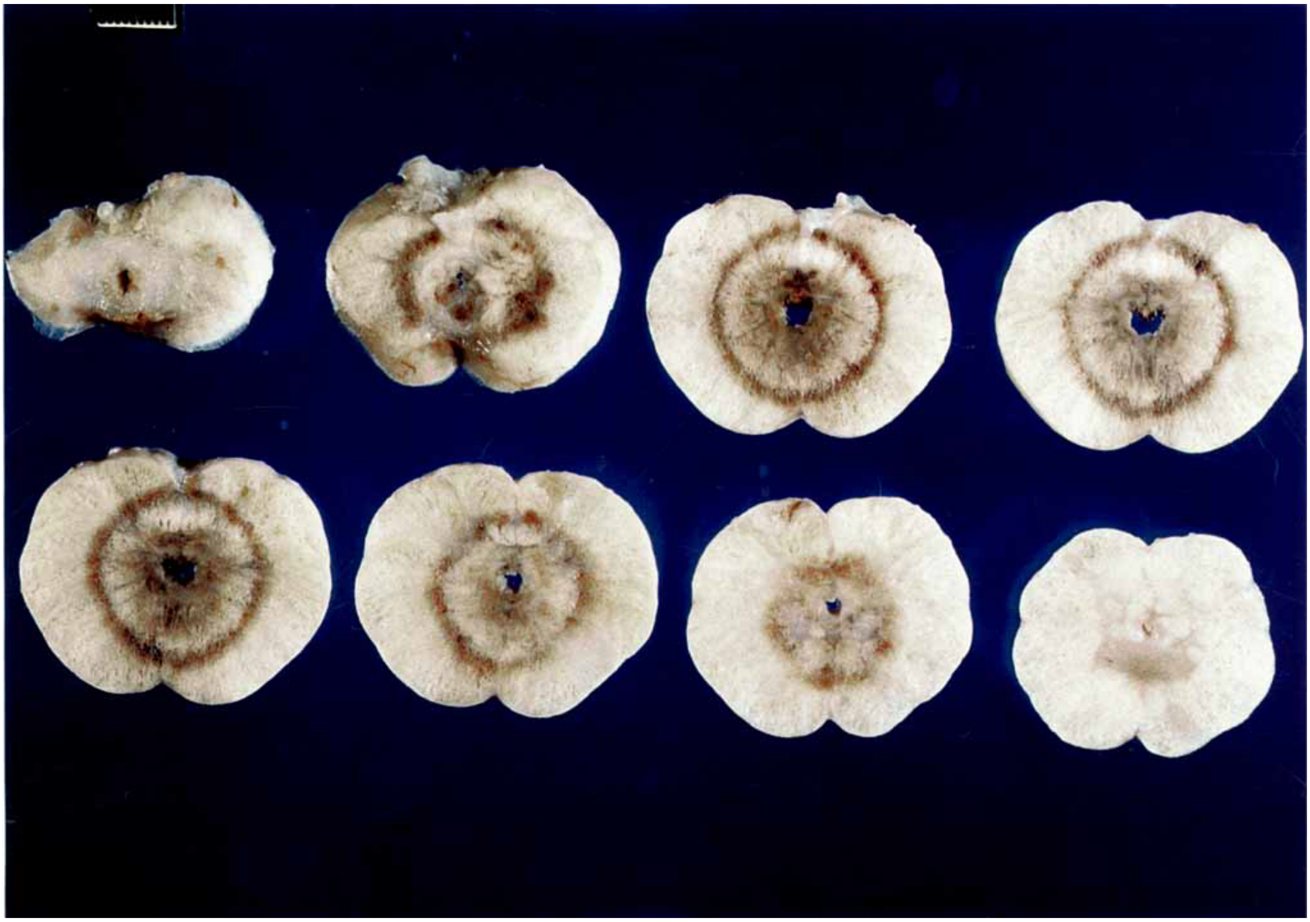

Fig. 1. Step-sectioned prostate from dog 7253 harvested 3 hours after VLAP with the 805-nm diode laser/diffuser fiber combination. Scale bar = 1 cm.

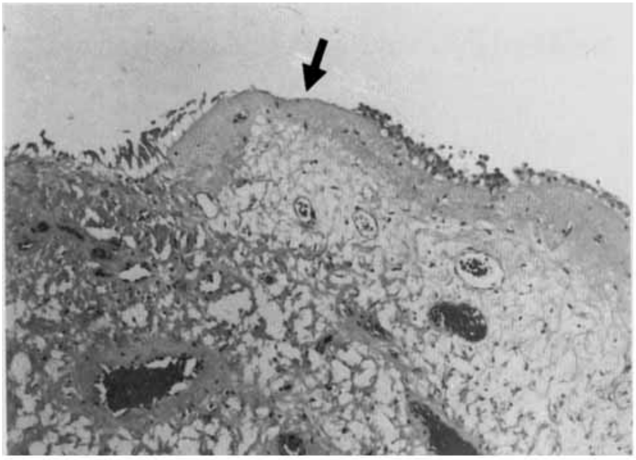

Fig. 2. At 3 hours after laser treatment, the transitional epithelium of the prostatic urethra is ulcerated (arrow). The lamina propria and muscular coat are edematous and necrotic. Hematoxylin and eosin, ×25.

Fig. 3. Hemorrhage in the necrotic zone is the dominant feature 24 hours after transurethral laser treatment of the prostate. (Hematoxylin and eosin, ×25.)

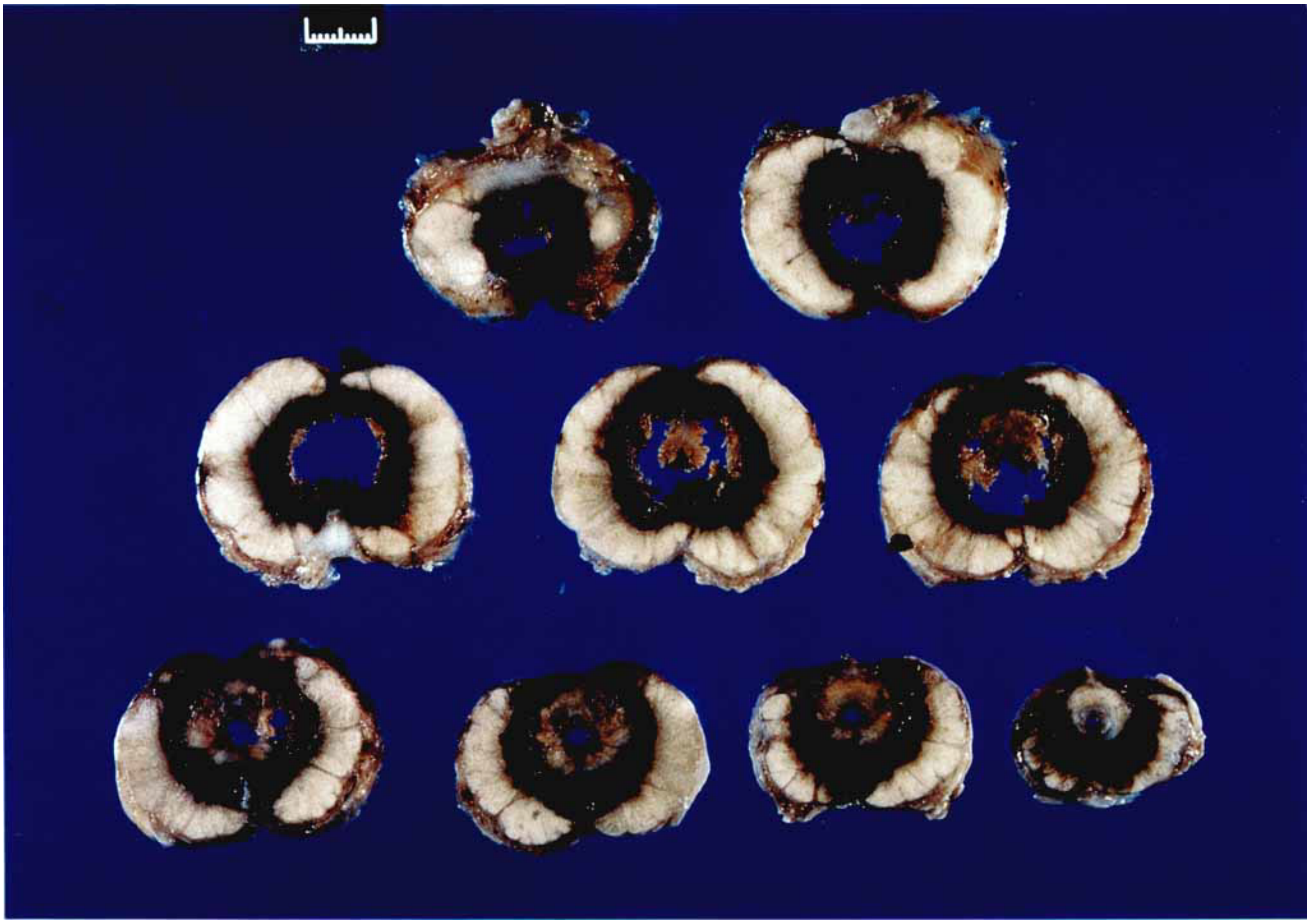

Fig. 4. Step-sectioned prostate from dog 1332 harvested 4 days after VLAP with the 805-nm diode laser/diffuser fiber combination. Scale bar = 1 cm.

size to that of the prostate 3 hours after surgery. However, hemorrhage was apparent in the necrotic region (Fig. 3). The peripheral viable tissue was edematous and infiltrated by neutrophils.

At 4 days (Fig. 4) and at 7 days after lasing the prostate, a distinct zone of hemorrhagic necrosis surrounded the urethra. Well-demarcated areas of normal glandular tissue were present subadjacent to the prostatic capsule. The viable prostate in the gland taken 7 days after treatment contained diffuse nonsuppurative inflammation.

Fourteen days after lasing (Fig. 5A,B), the central prostate had a cystic space filled with clotted blood. Scattered prostatic glands and ducts surviving subadjacent to the capsule exhibited squamous metaplasia, and the interstitium of this area contained focal accumulations of lymphocytes.

The prostate examined 21 days after laser treatment was inconsistent with the others in this series both in terms of what was judged to be preexisting structure and response to the laser treatment. This gland had no cystic areas of necrosis. The prostatic urethra was intact and of normal diameter. Overall, this prostate was the largest in the study. The increased size was caused by marked hypertrophy of infraglandular smooth muscle instead of by typical hyperplasia of prostatic glands and ducts. The stroma contained extensive lymphocytic inflammation.

The prostatic urethra in the 35- and 49-day specimens was prominently dilated to a diameter of approximately 2 cm (Fig. 6). The transitional epithelium was for the most part intact, and the lamina propria contained increased fibrous connective tissue. Irregularly shaped, attenuated lobules of prostatic glands and ducts were generally confined to the subcapsular periphery. The 35-day prostate contained a moderate amount of lymphocytic inflammation. In the 49-day gland, inflammation was severe and consisted of a mixture of lymphocytes and neutrophils. The inflammation involved both the urethra and glandular tissues (Fig. 7).

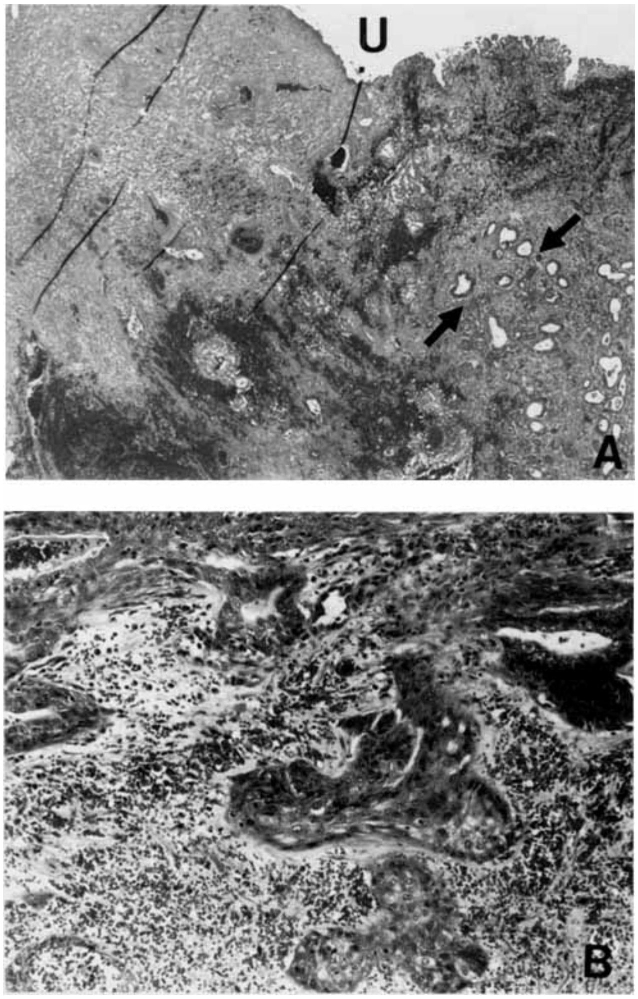

Fig. 5. **A:** This is a section of the tissue surrounding the dilated urethra (U) 14 days after laser treatment of the prostate. There is disseminated hemorrhage and the arrows point to surviving glands. Hematoxylin and eosin, ×25. **B:** Surviving prostatic glands exhibit squamous metaplasia. Hematoxylin and eosin, ×250.

DISCUSSION

The 1.06 Nd:YAG laser has demonstrated the ability to efficiently photocoagulate prostatic tissue in the dog model when delivered to the prostate transurethrally with either laterally deflecting [1,11] or diffuser fibers [9]. The high capital outlay required, coupled with large physical size and power/cooling requirements of some Nd:YAG lasers make widespread acceptance of VLAP as an office procedure problematic. A smaller machine that does not require special utilities and that could photocoagulate prostatic tissue as effectively as the Nd:YAG might be advantageous to both urologists and patients. In this study, when 15,000 J of diode laser energy was delivered to the prostate with the diffuser fiber, a consistent spherical "kill zone" averaging 2.08 cm in diameter resulted (2.22 cm if dog #793 is omitted from the results). This is somewhat less than the experience this laboratory has had with the 1.06 Nd:YAG/diffuser combination we have previously reported but is consistent with the findings of other investigators who have reported less sensitivity of

Fig. 6. Step-sectioned prostate from dog 645 harvested 49 days after VLAP with the 805 nm diode laser/diffuser fiber combination. Scale bar = 1 cm.

normal dog prostate to 805-nm diode laser energy [12]. Our results do demonstrate coagulation volumes that compare favorably with other investigators using the laterally deflecting fibers in combination with the 1.06 Nd:YAG laser.

Current VLAP techniques require placement of the fiber in a minimum of four locations. It has been suggested that in very large prostates, as many as eight treatment locations in the lateral lobes and two more in the median lobe might be indicated [2]. A possible disadvantage to this technique is that the high power density irradiation at each location frequently results in small submucosal explosions (the "popcorn effect") that increase the potential for bleeding and rupture of the prostatic capsule. This phenomena may also explain why many men have experienced dysuria and pain for several weeks postoperatively. The ability to photocoagulate the prostate by placing the fiber in one location and spreading the laser

Fig. 7. Prostate 49 days after treatment has widely spaced, irregularly shaped glands and ducts surrounded by stroma that contains dense, diffuse inflammation. Hematoxylin and eosin, ×25.

energy over a larger surface area could reduce both operative time and difficulty and would also offer the benefit of causing less trauma to the prostatic urethra that occurs with multiple fiber placements and high power densities. A prostatectomy that is even less traumatic to the urethra could offer shorter convalescence and hospitalization and a reduced incidence of irritative symptoms postoperatively. Previous work in this laboratory has demonstrated that transurethral delivery of 15,000 J of Nd:YAG energy via a diffuser fiber can produce similar volumes of coagulated tissue as can Nd:YAG/laterally deflecting fiber combinations [9]. This current study has shown that similar results can be obtained using a diffuser fiber combined with an 805-nm diode laser. Clinically, all eight dogs did well postoperatively. The one case of urine retention that was relieved by catheterization was probably due to an obstruction of the urethra caused by necrotic prostate tissue or hematoma. The unacceptably high incidence of urinary incontinence in dogs that have had conventional prostatectomies [13] continues to be nonexistent in dogs that have had transurethral laser prostatectomy.

Pathologic changes associated with transurethral laser prostatecomy in the dog with laterally deflecting delivery systems and 1.06 Nd: YAG lasers have been reported previously [11]. When used at 60 watts of power for 60 seconds per prostatic quadrant to deliver a total dose of 14,400 J the results have been shown to be remarkably consistent. The pathologic changes in the prostates of this study at similar time points are essentially identical with those resulting from both 1.06 Nd:YAG/laterally deflecting fiber [11] and 1.06 Nd:YAG/diffuser fiber [9] combinations previously tested. The area of photothermal necrosis was remarkably concentric in all but one dog in this study. The prostate harvested at 3 weeks (dog 793) had little thermal damage that could be associated with the laser treatment. This prostate was judged to have had preexisting abnormalities relating to increased amounts of fibromuscular tissue in the gland. Epithelial-to-stromal ratio differences between the dog and human are thought to be responsible for the differences in defect size seen in the human prostate treated by VLAP [14] and probably account for larger amounts of energy per gram of tissue required to ablate human prostates.

The consistent picture of tissue destruction and healing between these laser/fiber combinations suggests that efficient transmission of adequate doses of laser energy into the prostate is of primary importance. Motamedi et al. [15] have shown that surface cooling of the urethra and lower power settings prevent the formation of surface char and, therefore, allow more efficient penetration of the laser energy into the deep tissues of the prostate. We experienced this same phenomena with the diffusing fiber as evidenced by obtaining similar tissue coagulation volumes while inflicting very little visible changes in the urethral mucosa immediately postoperatively (the visual effect of the prostatic urethra immediately after lasing is one slightly blanched with no visible destruction of the urethral mucosa). Not only does this technique efficiently ablate prostatic glandular tissue, it is attended by a much lower incidence of postoperative complications than conventional prostatectomies or VLAP with laterally deflecting fibers in the dog model [16].

In conclusion, we believe that this study has shown that the 805-nm diode laser combined with a diffusing fiber can efficiently ablate volumes of prostate tissue with similar pathologic changes as does the Nd:YAG with both laterally deflecting and diffuser fiber delivery systems. We also believe this laser/fiber combination offers the additional advantages of simplified technique and a lower operating cost.

ACKNOWLEDGMENTS

This study was supported by grant NIH-NCI CA-16672 awarded by the National Cancer Institute. Animals are maintained in facilities approved by the American Association for Accreditation of Laboratory Animal Care and in accordance with current United States Department of Agriculture, Department of Health and Human Services, and National Institutes of Health regulations and standards.

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